MULTIWAVELENGTH LASER PROPAGATION STUDY -- III

Quarterly Progress Report No. 3

J. Richard Kerr

Oregon Graduate Center
for Study and Research
Portland, Oregon

April, 1971

Sponsored by

Advanced Research Projects Agency
ARPA Order No. 306

14

ACKNOWLEDGEMENT

This research was supported by the Advanced Research Projects Agency of the Department of Defense, and was monitored by the Office of Naval Research under Contract N00014-68-0461-0001.

SUMMARY

During this period the data described in the preceeding report were processed further to yield improved information on the spectrum of multiwavelength scintillations andthe validity of the hypothesis of "frozen-in" turbulence. Also, experiments were formulated to examine the fundamental intermittency of turbulence and scintillation phenomena.

A paper was prepared for publication, summarizing the principal results to date.

CONTENTS

I. INTRODUCTION

During this period the data described in the "standard runs" of the preceeding report[1] were processed further to yield improved information on the spectrum of multiwavelength scintillations and the validity of the hypothesis of "frozen-in" turbulence. These results will be given below. In addition, experiments were formulated to examine the fundamental intermittency of turbulence and scintillation phenomena.[2]

A paper was prepared for publication, summarizing the principal results to date. A preprint will be distributed in the near future.

II. RESULTS ON SCINTILLATION SPECTRA

If we define the temporal spectral density of the log amplitude fluctuations as $W(f)$, the frequency for which $fW(f)$ is a maximum is of interest. We define this frequency as f_m, and note that the theory predicts that the following dimensionless quantity is a constant:[3,4]

$$\frac{f_m(\lambda L)^{1/2}}{v_\perp} = (\text{constant}) \quad , \qquad (1)$$

where λ is the wavelength, L is the pathlength, and $v_\perp$ is the perpendicular component of the wind velocity relative to the optical path. This is a consequence of the Taylor hypothesis, where $(\lambda L)^{1/2}$ represents the "frozen-in" transverse amplitude correlation length. In view of the covariance results presented in the preceeding report,[1] it is suggested that the latter quantity be replaced by the correlation length actually measured in each run. This quantity has been denoted[1] by r_a.

We have obtained values of f_m from the spectra of intensity--rather than log amplitude--fluctuations. This has been a common practice in the literature, and results in substantially the same values as would be obtained from the logarithmic quantity.

Although our path was not instrumented sufficiently to assure uniform wind conditions along the path, it is possible to normalize-out the wind velocity. For example, in Figure 1a,b we show the ratio of f_m at two wavelengths, vs. turbulence strength. The average of all points was within ten percent of the theoretical ratio $(\lambda_1/\lambda_2)^{1/2}$ implied by Eq. (1). It may be expected that the ratio will decrease under saturated conditions at the shorter wavelengths, due to the increase in r_a described in the preceeding report.[1] This has been observed elsewhere.[5] In the present case, no clear trend with increasing turbulence is evident, which suggests that the amplitude pattern may evolve more (less frozen-in) under high-scintillation conditions.

This conjecture is further supported by Figure 2a,b, in which the two-wavelength ratios of $f_m r_a$ are plotted vs. turbulence strength. From the Taylor hypothesis, these ratios would be expected to be unity. Since the 10.6μ scintillations are not saturated,[1] the increase which is observed at higher turbulence levels indicates a breakdown in the frozen-in nature of the amplitude pattern at 4880Å and 1.15μ.

Scatter plots of the quantity of Eq. (1) show substantial spread, due in part to the uncertainty in the uniformity of the wind velocity over the path. The average of forty-eight data points (all three wavelengths combined) was 1.6. The quantity $f_m r_a/v_\perp$ evidenced less spread

and had an average value near unity.

III. PLANS FOR THE FOLLOWING PERIOD

During the following period, we will perform experiments which treat such quantities as C_n^2 and scintillation log amplitude variances as stochastic quantities.[2] We will then commence experiments on transmitter aperture effects.

REFERENCES

1. The preceeding report on this program is

   Multiwavelength Laser Propagation Study -- III
   Quarterly Progress Report No. 2
   January, 1971

2. Special meeting on atmospheric propagation, Rome Air Development Center, January 20-21, 1971. The implications of the fundamental intermittency of turbulence and scintillations are under theoretical study by S. Collins, Ohio State University; P. M. Livingston, Naval Research Laboratory; and D. A. deWolf, RCA Laboratories.

3. R. S. Lawrence and J. W. Strohbehn, "A Survey of Clear-Air Propagation Effects Relevant to Optical Communications," Proc. IEEE, vol. 58, October 1970, pp. 1523-1545.

4. V. I. Tatarski, Wave Propagation in a Turbulent Medium, New York: 1961, McGraw-Hill.

5. M. E. Gracheva, "Research into the Statistical Properties of the Strong Fluctuations of Light when Propagated in the Lower Layer of the Atmosphere," Izv. Vyssh. Ucheb. Zaved. Radiofiz., vol. 10, pp. 775-787, 1967.

LIST OF FIGURES

FIGURE 1a

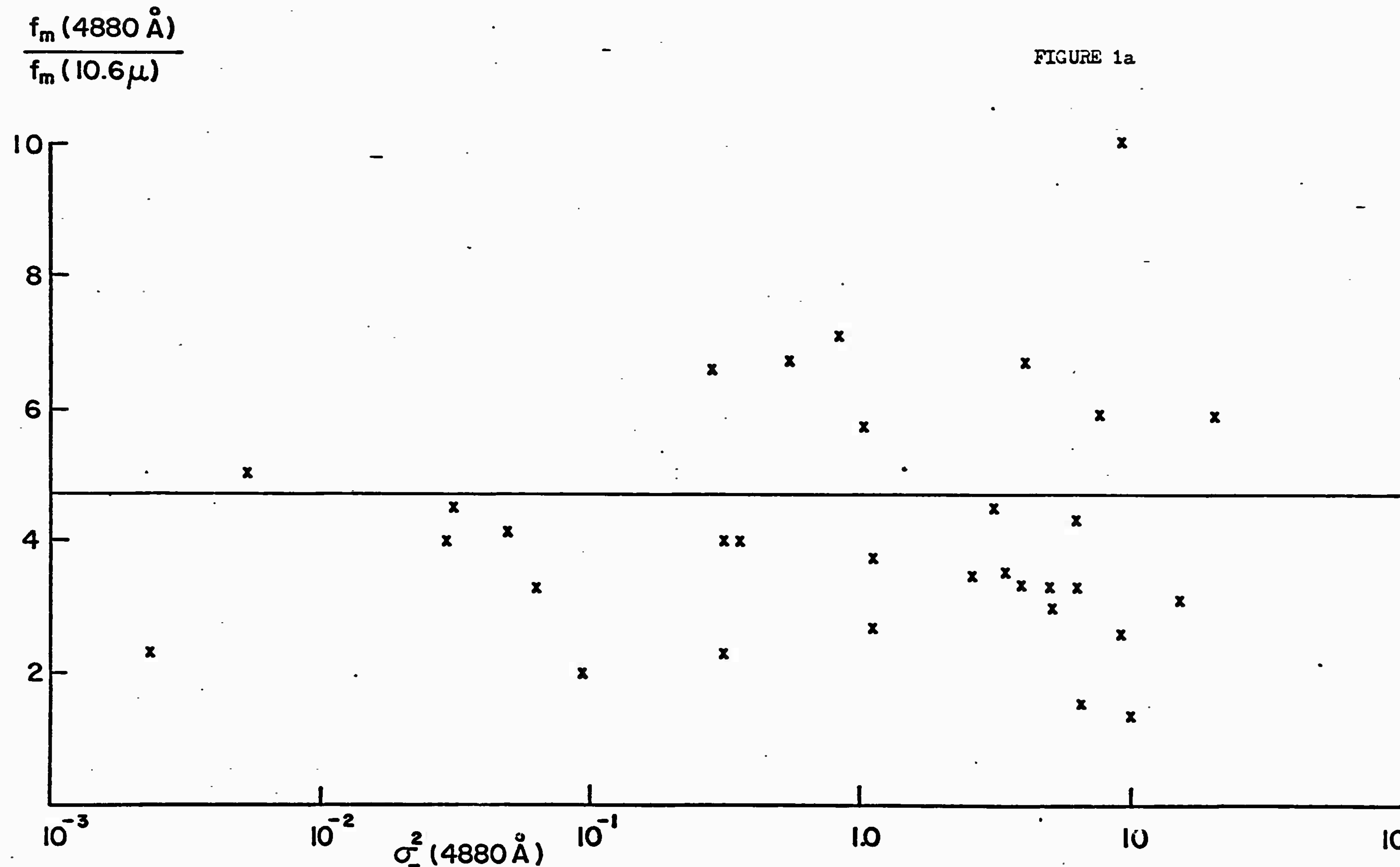
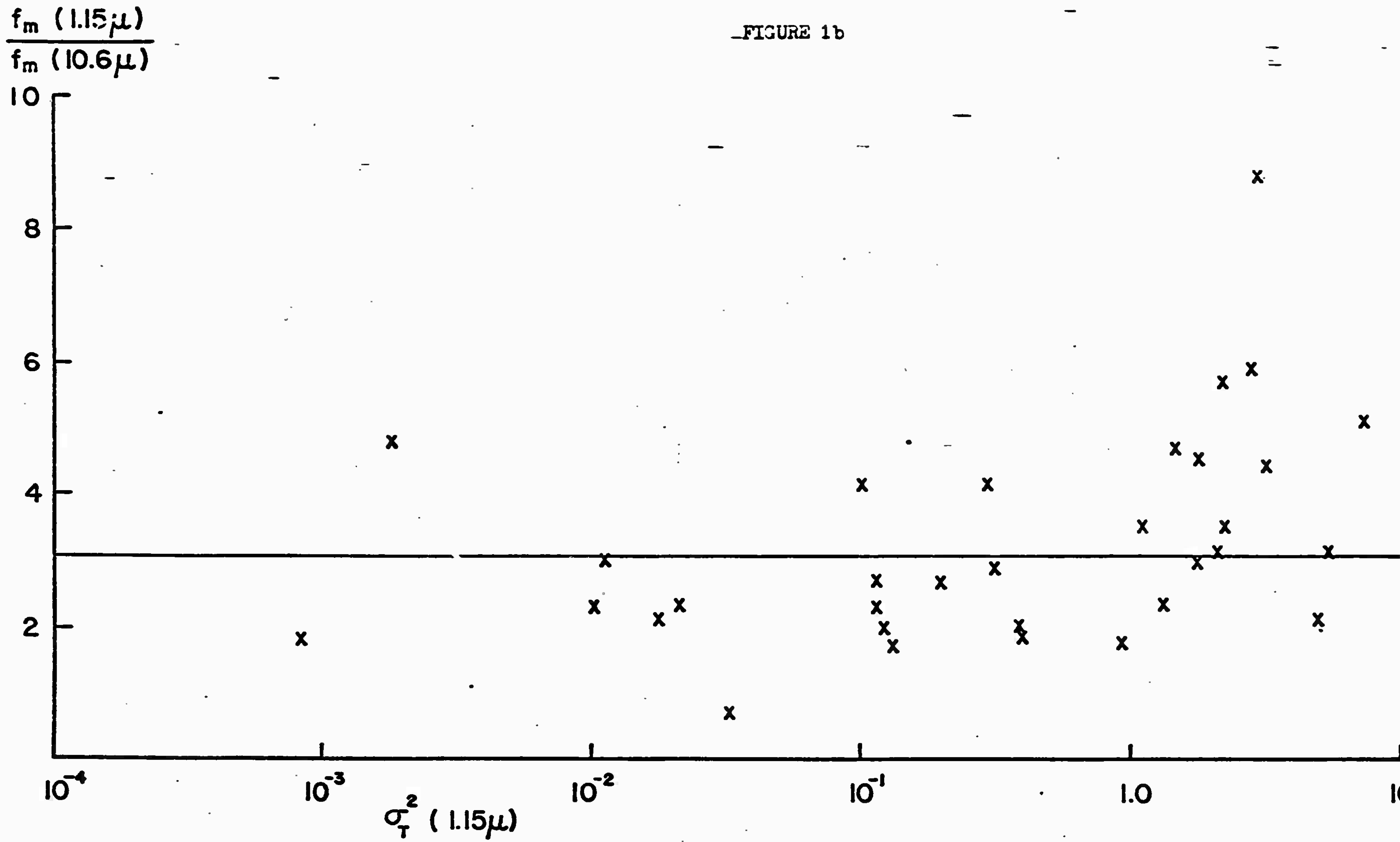


FIGURE 1b


$\frac{f_m\ (1.15\mu)}{f_m\ (10.6\mu)}$
10
8
6
4
2
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1.0
10
σ_T^2 (1.15μ)

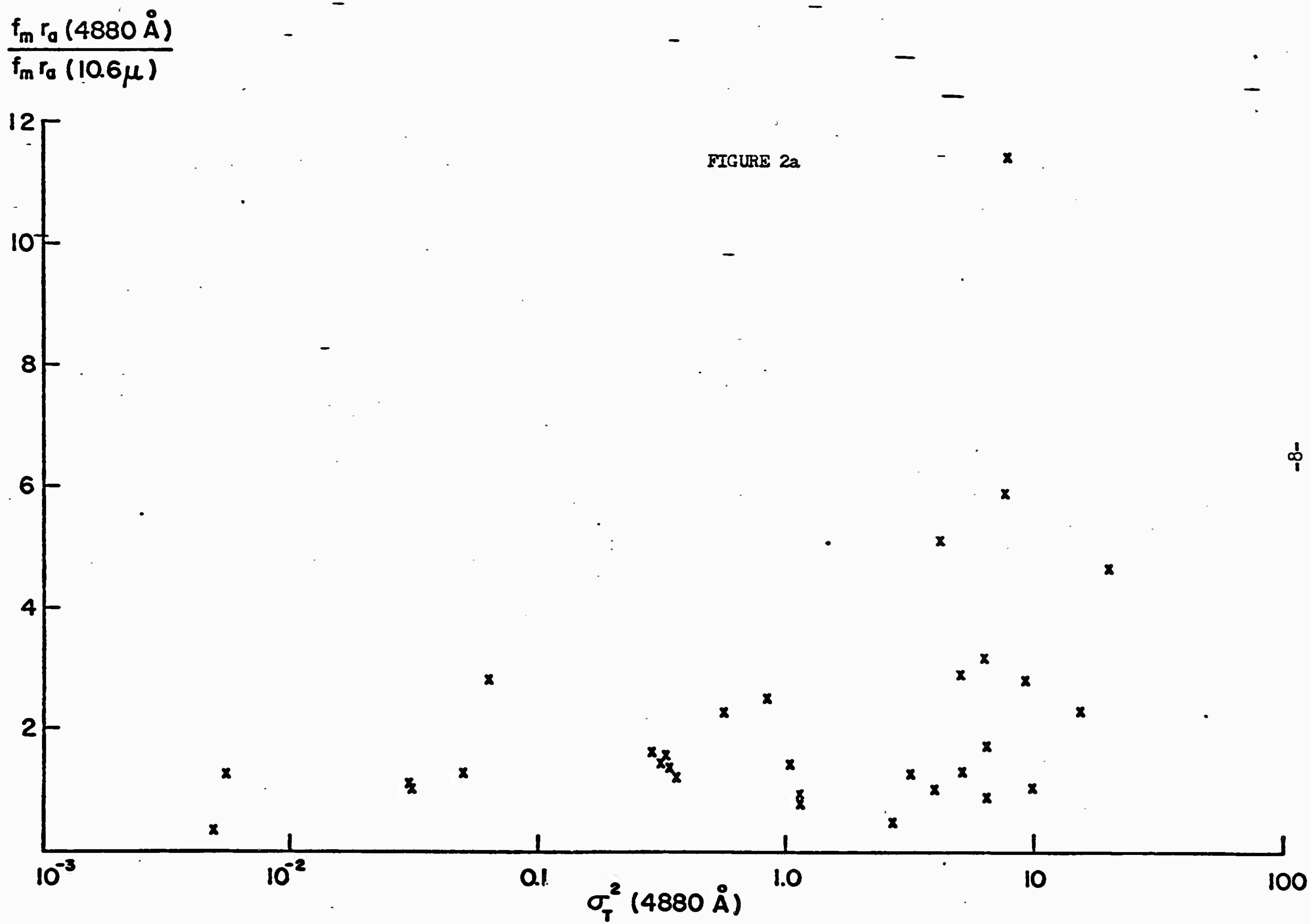
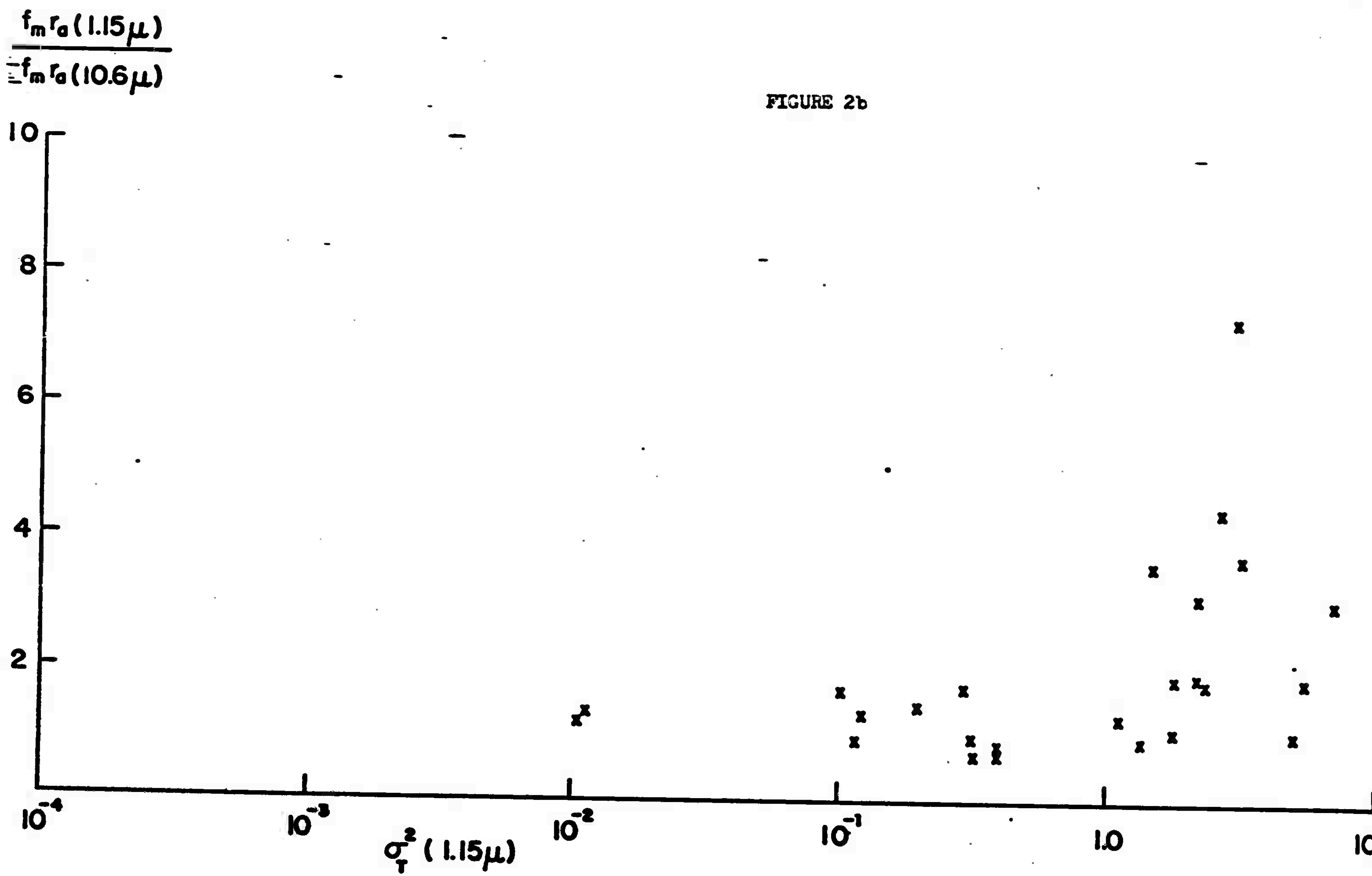


FIGURE 2a

FIGURE 2b



$\frac{f_m r_a(1.15\mu)}{f_m r_a(10.6\mu)}$
10
8
6
4
2
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1.0
10
$\sigma_T^2\,(1.15\mu)$

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Oregon Graduate Center 9340 SW Barnes Road Portland, Oregon 97225	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

MULTIWAVELENGTH LASER PROPAGATION STUDY -- III

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Third quarterly report; December 15, 1970-March 15, 1971

5. AUTHOR(S) (First name, middle initial, last name)

J. Richard Kerr

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April, 1971	9	5

8a. CONTRACT OR GRANT NO. N00014-68A0461-0001 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 1154-11 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Department of Defense--Pentagon Washington, D.C. 20301

13. ABSTRACT

During this period the data described in the preceeding report were processed further to yield improved information on the spectrum of multiwavelength scintillations and the validity of the hypothesis of "frozen-in" turbulence. Also, experiments were formulated to examine the fundamental intermittency of turbulence and scintillation phenomena.

A paper was prepared for publication, summarizing the principal results to date.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6811

Unclassified

Security Classification

A-31408